NMR Detection of Extant Life

Completed Technology Project (2017 - 2018)

Project Introduction

Recent advances in the miniaturization of NMR (Nuclear Magnetic Resonance) spectrometers opens the possibility of utilizing this technology for molecular spectroscopy in remote environments. The ability of NMR to monitor inter-molecular and intra-molecular interactions, including those of macromolecules (e.g., amino acids, carbohydrates, nucleic acids), makes NMR spectroscopy a powerful tool in chemical and medical applications, especially for metabolite/biomarker discovery in the search of life on other planets and moons. An NMR system consists of a magnet that produces a static magnetic field (B0), radiofrequency (RF) coil(s) for exciting and detecting nuclear spins, an RF transceiver and digitizing electronics. The hydrogen nucleus (1H) has the highest sensitivity among stable nuclei for NMR detection. Other nuclei are possible for NMR spectroscopy, however, their natural abundance and relatively weak magnetic moments makes detection more difficult with adequate SNR (Signal to Noise Ratio). We, at the University of Minnesota, have developed a transceiver in 0.13-µm CMOS technology, which draws 12mA from a single 1.5V supply, i.e., 18 mW, and occupies an active area of 2mm2. The detection of multiple nuclei in our NMR receiver design was validated using chemical samples of adenosine triphosphate (ATP) for phosphorus (31P), benzene (C6H6) for carbon (13C) and ethanol (CH3CH2OH) for proton (1H) in a 5T magnet. Our NMR system for extant life detection will focus on adapting the NMR chip to a 1.0 T palm-sized permanent magnet recently used in mini bio-sensor MRI applications. Special considerations for the miniature NMR spectrometer include maintaining the magnet at a constant temperature to minimize magnetic field drift during data acquisition and sample temperature needs to be above the freezing point of water. Sample Field locking, via tracking the resonant frequency of D2O, will compensate for possible magnetic field drifting thereby insuring spectrum integrity. Presently, the aqueous geochemistry of oceans below the frozen surfaces of Europa and Enceladus are unknown. If extant life exists, the basis of life may not resemble that of earth-based life, therefore it is necessary to have a capability to characterize whatever molecules are present in these aqueous environments. Either liquid aqueous samples obtained from the subsurface ocean or frozen aqueous samples from geyser plumes can be collected. The solute concentration may be small, making it necessary to have the capability of increasing the solute concentration of collected samples. To increase metabolite/biomarker concentration for NMR detection we propose lyophilizing several samples, combining them, then rehydrating with D2O for NMR analysis. The lyophilizer will be developed by BioServe Space Technologies (University of Colorado) which has over 25 years of experience in developing space flight certified hardware to support life science research. In summary, the University of Minnesota and BioServe Space Technologies propose to co-develop a portable NMR spectrometer and a system for increasing the concentration of molecules of sampled ocean water by lyophilization. The proposed integrated system is inherently capable of operating in a high-radiation environment with minimal power and data bandwidth requirements.

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Concepts for Ocean Worlds Life Detection Technology

Project Management

Program Director:

Carolyn R Mercer

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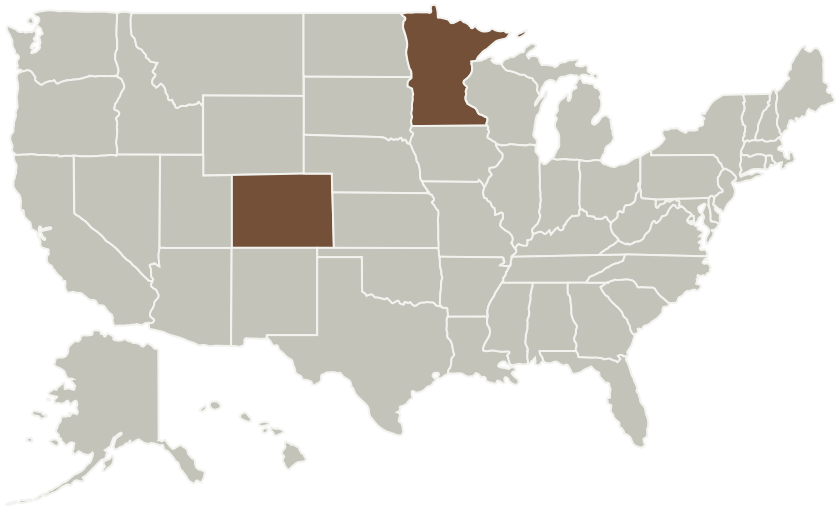
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Minnesota-Twin Cities	Supporting Organization	Academia Asian American Native American Pacific Islander (AANAPISI)	Minneapolis, Minnesota

Primary U.S. Work Locations	
Colorado	Minnesota

Project Management *(cont.)*

Program Manager:

Carolyn R Mercer

Principal Investigator:

Bruce E Hammer

Co-Investigators:

Kevin J Mckoskey
Louis S Stodieck
Ramesh Harjani

Technology Areas

Primary:

- TX04 Robotic Systems
  - TX04.3 Manipulation
    - TX04.3.4 Sample Acquisition and Handling

Target Destination

Others Inside the Solar System